

CLAIMS

What is claimed is:

1. A method for forming an antibacterial coating on live tissue or a medical article comprising:
 - 5 a) applying to a live tissue region or a medical article surface a siloxanol polymer composition produced by combining:
 - i) an acidic aqueous component including divalent metal cations; and
 - 10 ii) a non-aqueous component including a silane having a formula $\text{RSi}(\text{OR}^1)_3$, wherein R is a radical selected from the group consisting of lower alkyl, vinyl, phenyl, 3,3,3-trifluoropropyl, γ -glycidyloxypropyl, and γ -methacryloxypropyl, and R^1 is a hydrolyzable hydrocarbyl group, at least about 70 percent by weight of
15 the silane being $\text{CH}_3\text{Si}(\text{OCH}_3)_3$; and
 - b) curing the siloxanol polymer, thereby forming the antimicrobial coating.
2. A method for forming an antimicrobial coating on live tissue or a medical article comprising:
 - 20 a) combining an acidic aqueous dispersion of divalent metal cation selected from the group consisting of Ca^{+2} , Mn^{+2} , Zn^{+2} , and Cu^{+2} , said dispersion containing sufficient acid to provide a pH of from about 2.2 to about 2.8 with a non-aqueous composition comprising at least one trialkoxy silane of the formula $\text{RSi}(\text{OR}^1)_3$,
25 wherein R is a radical selected from the group consisting of lower alkyl, vinyl, phenyl, 3,3,3-trifluoropropyl, γ -glycidyloxypropyl,

and γ -methacryloxypropyl, and R^1 is a hydrolyzable hydrocarbyl group, at least about 70 percent by weight of the silane being $\text{CH}_3\text{Si}(\text{OCH}_3)_3$;

- 5 b) allowing the resulting mixture to stand until the pH increases to at least about 2.5, whereby the silane is hydrolyzed to silanol and the silanol is partially condensed to a siloxanol polymer; whereby the amount of divalent metal cation in the acidic aqueous dispersion is from about 1.2 to about 2.4 millimoles, per molar equivalent of the silane sesquioxide, calculated as methyl silane sesquioxide, and further wherein at least one of the aqueous dispersion and the non-aqueous composition further comprises a volatile organic solvent;
- 10 c) applying the mixture including the siloxanol polymer to a live tissue region or surface of a medical article; and
- 15 d) curing the siloxanol polymer to form silane sesquioxide, thereby forming the antimicrobial coating, wherein the divalent metal cations are present in the aqueous dispersion in an amount of from about 1.2 millimoles to about 2.4 millimoles, per molar equivalent of the partial condensate,
- 20 calculated as methyl silane sesquioxide.

3. A medical article comprising an antimicrobial coating that is produced by curing a partial condensate of a silanol of the formula $\text{RSi}(\text{OH})_3$, wherein R is selected from the group consisting of lower alkyl, vinyl, phenyl, 3,3,3-trifluoropropyl, γ -glycidylloxypropyl, and γ -methacryloxypropyl and wherein at least about 70 percent by weight of the silanol is $\text{CH}_3\text{Si}(\text{OH})_3$, and the partial condensate of the silanol is present in an acidic composition that includes an aqueous-organic solvent and divalent metal cations.
- 25

4. The medical article of Claim 3, wherein the partial condensate is formed by hydrolyzing a silane of the formula $\text{RSi}(\text{OR}^1)_3$, wherein R^1 is a hydrolyzable hydrocarbyl group, at least about 70 percent by weight of the silane being $\text{CH}_3\text{Si}(\text{OCH}_3)_3$;
- 5 5. A medical article comprising an antimicrobial coating that is produced by curing a partial condensate of a silanol of the formula $\text{RSi}(\text{OH})_3$, wherein R is selected from the group consisting of lower alkyl, vinyl, phenyl, 3,3,3-trifluoropropyl, γ -glycidyoxypropyl, and γ -methacryloxypropyl and wherein at least about 70 percent by weight of the silanol is $\text{CH}_3\text{Si}(\text{OH})_3$, and wherein the partial
10 condensate of the silanol is present in an acidic composition that includes an aqueous-organic solvent and colloidal silica.
6. A method for forming an antimicrobial coating on live tissue or a medical article, comprising:
 - a) applying to a live tissue region or a medical article surface an
15 aqueous coating composition comprising a dispersion of divalent metal cations in lower aliphatic alcohol-water solution of the partial condensate of at least one silanol of the formula $\text{RSi}(\text{OH})_3$, wherein R is a radical selected from the group consisting of lower alkyl, vinyl, phenyl, 3,3,3-trifluoropropyl, γ -glycidyoxypropyl,
20 and γ -methacryloxypropyl, at least about 70 percent by weight of the silanol being $\text{CH}_3\text{Si}(\text{OH})_3$, acid in amount to provide a pH in the range of from about 2.5 to about 6.2, and said divalent metal cations in an amount of from about 1.2 millimoles to about 2.4 millimoles, per molar equivalent of the partial condensate,
25 calculated as methyl silane sesquioxide; and
 - b) allowing the aliphatic alcohol and water of the aqueous coating composition to evaporate and the partial condensate to cure to the

corresponding silane sesquioxide, thereby forming the antimicrobial coating.

7. A medical article comprising an antimicrobial coating that is formed by reacting:
- a) a silane component of the formula $R^1Si(OR^2)_3$, wherein, R^1 is a lower alkyl group, a phenyl group or a vinyl, an acrylic, an amino, a mercapto, or a vinyl chloride functional group; and each R^2 is independently a lower alkyl group;
 - b) at least one of:
 - i) a base component selected from the group consisting of a metal hydroxide, an aminosilane and a ketosilane; or
 - ii) an acid component selected from the group consisting of a water-soluble organic acid, boric acid and phosphorous acid or salt thereof; and
 - c) water.
8. A method for forming an antimicrobial coating on live tissue or a medical article comprising:
- a) applying to a live tissue region or a surface of a medical article a mixture formed by combining at least one silane of the formula $R^1Si(OR^2)_3$, wherein R^1 is a lower alkyl group, a phenyl group or a bifunctional silane containing vinyl, acrylic, amino, or vinyl chloride functional group and R^2 is a lower alkyl group with at least one component selected from the group consisting of colloidal aluminum hydroxide and a metal alcoholate of the formula $M(OR^3)_m$, wherein M is a metal of valence m, R^3 is a lower alkyl group, m is an integer of 3 or 4, and water; and
 - b) curing the mixture, thereby forming the antimicrobial coating.

9. A method for forming an antimicrobial coating on live tissue or a medical article, comprising:
- a) applying to a live tissue region or a surface of a medical article a non-metallic aqueous coating composition formed by combining:
 - 5 i) at least one silane of the formula $R^1Si(OR^2)_3$, wherein R^1 is a lower alkyl group, a phenyl group or a functional group including at least one of vinyl, acrylic, amino, mercapto, or vinyl chloride functional group and R^2 is a lower alkyl group;
 - 10 ii) (3-(2-aminoethylamino)propyltrimethoxysilane or 3-aminopropyltrimethoxysilane;
 - iii) water;
 - iv) epoxide silane;
 - v) lower alkanol; and
 - 15 b) curing the coating composition, thereby forming the antimicrobial coating.
10. A method for forming an antimicrobial coating on live tissue or a medical article, comprising:
- a) applying to a live tissue region or a surface of a medical article a non-metallic aqueous coating composition formed by combining:
 - 20 i) at least one silane of the formula $R^1Si(OR^2)_3$ wherein R^1 is a lower alkyl group, a phenyl group or a functional group including at least one of vinyl, acrylic, amino, mercapto,

- or vinyl chloride functional group; and R^2 is a lower alkyl group;
- 5 ii) at least one alkali component comprising an hydroxide or carbonate of divalent metal;
- iii) boric acid;
- iv) water;
- v) ethyl polysiloxane; and
- vi) lower alkanol; and
- 10 b) curing the coating composition, thereby forming the antimicrobial coating.
11. A method for forming an antimicrobial coating on live tissue or a medical article comprising:
- a) applying to a live tissue region or a surface of a medical article a composition obtained by combining:
- 15 i) at least two silanes represented, independently, by formula $R^1Si(OR^2)_3$ wherein at least one R^1 represents a lower alkyl group in at least one silane of formula, at least one R^1 represents a group containing a functional mercapto group, and any other R^1 groups may represent a phenyl group, or a functional group including at least one of
- 20 vinyl, acrylic, amino, or vinyl chloride functional group; and R^2 represents a lower alkyl group; and
- ii) lower alkanol; and
- b) curing the coating composition, thereby forming the antimicrobial coating.
- 25

12. A method for forming an antimicrobial coating on live tissue or a medical article comprising:
- 5 a) applying to a live tissue region or a surface of a medical article a composition, which in combination with water, forms a neutral or basic composition, wherein the composition comprises the product obtained by combining in a lower alkanol solvent, at least two silanes, represented independently by formula $R^1Si(OR^1)_3$ wherein at least one R^1 represents lower alkyl group, at least one R^1 represents a group, containing a functional amino group, any
- 10 other R^1 group represents, phenyl, or a functional group including at least one of vinyl, acrylic, or vinyl chloride functional group, R^2 represents lower alkyl group; and
- b) curing the composition, thereby forming the antimicrobial coating on the medical article.
- 15 13. A method for coating live tissue or a medical article, comprising:
- a) applying to a live tissue region or a surface of a medical article a non-metallic non-aqueous coating composition formed by combining:
- 20 i) at least one silane of formula $R^1Si(OR^2)_{4-n}$ wherein R^1 represents a lower alkyl group, an aryl group or a functional group containing at least one of vinyl, acrylic, amino, mercapto, or vinyl chloride functional groups; R^2 represents a lower alkyl group; and, n is a number of 1 to 2; and
- 25 ii) at least one compound selected from the group consisting of vinyltriacetoxysilane, colloidal aluminum hydroxide

and at least one metal alcoholate of formula $M(OR^3)_m$
wherein M represents a metal of valence m, R^3 represents
a lower alkyl group, and m is a number of 2 to 4; and

- 5 b) curing the coating composition, thereby forming the antimicrobial
coating.

14. A method for inhibiting or preventing microbial infections comprising:

- a) applying to live tissue or to a medical article substrate a siloxanol
polymer composition produced by combining:
- 10 i) an acidic aqueous component including divalent metal
cations; and
- ii) a non-aqueous component including a silane having a
formula $RSi(OR^1)_3$, wherein R is a radical selected from
the group consisting of lower alkyl, vinyl, phenyl,
3,3,3-trifluoropropyl, γ -glycidyloxypropyl, and
15 γ -methacryloxypropyl, and R^1 is a hydrolyzable
hydrocarbyl group, at least about 70 percent by weight of
the silane being $CH_3Si(OCH_3)_3$; and
- b) curing the siloxanol polymer, thereby forming on the live tissue
or the medical article substrate a coating that inhibits or prevents
20 colonization or growth of microorganisms.

15. A method for inhibiting or preventing microbial infections comprising:

- a) combining an acidic aqueous dispersion of divalent metal cation
selected from the group consisting of Ca^{+2} , Mn^{+2} , Zn^{+2} , and Cu^{+2} ,
said dispersion containing sufficient acid to provide a pH of from
25 about 2.2 to about 2.8 with a non-aqueous composition

- 5 comprising at least one trialkoxy silane of the formula $\text{RSi}(\text{OR}^1)_3$,
wherein R is a radical selected from the group consisting of lower
alkyl, vinyl, phenyl, 3,3,3-trifluoropropyl, γ -glycidyloxypropyl,
and γ -methacryloxypropyl, and R^1 is a hydrolyzable hydrocarbyl
group, at least about 70 percent by weight of the silane being
 $\text{CH}_3\text{Si}(\text{OCH}_3)_3$;
- 10 b) allowing the resulting mixture to stand until the pH increases to at
least about 2.5, whereby the silane is hydrolyzed to silanol and
the silanol is partially condensed to a siloxanol polymer; whereby
the amount of divalent metal cation in the acidic aqueous
dispersion is from about 1.2 to about 2.4 millimoles, per molar
equivalent of the silane sesquioxide, calculated as methyl silane
sesquioxide, and further wherein at least one of the aqueous
dispersion and the non-aqueous composition further comprises a
15 volatile organic solvent;
- c) applying the mixture including the siloxanol polymer to live
tissue or a medical article substrate; and
- 20 d) curing the siloxanol polymer to form silane sesquioxide, thereby
forming on the live tissue or the medical article substrate a
coating that inhibits or prevents colonization or growth of
microorganisms,
- 25 wherein the divalent metal cations are present in the aqueous
dispersion in an amount of from about 1.2 millimoles to about 2.4
millimoles, per molar equivalent of the partial condensate,
calculated as methyl silane sesquioxide.

16. A method for inhibiting or preventing microbial infections comprising:
- 5 a) applying to live tissue or a medical article substrate an aqueous coating composition comprising a dispersion of divalent metal cations in lower aliphatic alcohol-water solution of the partial condensate of at least one silanol of the formula RSi(OH)_3 , wherein R is a radical selected from the group consisting of lower alkyl, vinyl, phenyl, 3,3,3-trifluoropropyl, γ -glycidyloxypropyl, and γ -methacryloxypropyl, at least about 70 percent by weight of the silanol being $\text{CH}_3\text{Si(OH)}_3$, acid in amount to provide a pH in
- 10 the range of from about 2.5 to about 6.2, and said divalent metal cations in an amount of from about 1.2 millimoles to about 2.4 millimoles, per molar equivalent of the partial condensate, calculated as methyl silane sesquioxide; and
- 15 b) allowing the aliphatic alcohol and water of the aqueous coating composition to evaporate and the partial condensate to cure to the corresponding silane sesquioxide, thereby forming on the live tissue or the medical article substrate a coating that inhibits or prevents colonization or growth of microorganisms.
17. A method for inhibiting or preventing microbial infections comprising:
- 20 a) applying to a live tissue or a medical article substrate a mixture formed by combining at least one silane of the formula $\text{R}^1\text{Si(OR}^2)_3$, wherein R^1 is a lower alkyl group, a phenyl group or a bifunctional silane containing vinyl, acrylic, amino, or vinyl chloride functional group and R^2 is a lower alkyl group with at
- 25 least one component selected from the group consisting of colloidal aluminum hydroxide and a metal alcoholate of the

formula $M(OR^3)_m$, wherein M is a metal of valence m, R^3 is a lower alkyl group, m is an integer of 3 or 4, and water; and

- 5 b) curing the mixture, thereby forming on the live tissue or the medical article substrate a coating that inhibits or prevents colonization or growth of microorganisms.

18. A method for inhibiting or preventing microbial infections comprising:

- a) applying to live tissue or a medical article substrate a non-metallic aqueous coating composition formed by combining:
- 10 i) at least one silane of the formula $R^1Si(OR^2)_3$, wherein R^1 is a lower alkyl group, a phenyl group or a functional group including at least one of vinyl, acrylic, amino, mercapto, or vinyl chloride functional group and R^2 is a lower alkyl group;
- ii) (3-(2-aminoethylamino)propyltrimethoxysilane or 3-aminopropyltrimethoxysilane;
- 15 iii) water;
- iv) epoxide silane;
- v) lower alkanol; and
- b) curing the coating composition, thereby forming on the live tissue or the medical article substrate a coating that inhibits or prevents
- 20 colonization or growth of microorganisms.

19. A method for inhibiting or preventing microbial infections comprising:

- a) applying to live tissue or a medical article substrate a non-metallic aqueous coating composition formed by combining:

- 5
- i) at least one silane of the formula $R^1Si(OR^2)_3$ wherein R^1 is a lower alkyl group, a phenyl group or a functional group including at least one of vinyl, acrylic, amino, mercapto, or vinyl chloride functional group; and R^2 is a lower alkyl group;
 - ii) at least one alkali component comprising an hydroxide or carbonate of divalent metal;
 - iii) boric acid;
 - iv) water;
 - 10 v) ethyl polysiloxane; and
 - vi) lower alkanol.
- b) curing the coating composition, thereby forming on the live tissue or the medical article substrate a coating that inhibits or prevents colonization or growth of microorganisms.
- 15 20. A method for inhibiting or preventing microbial infections comprising:
- a) applying to live tissue or a medical article substrate a composition obtained by combining:
 - i) at least two silanes represented, independently, by formula $R^1Si(OR^2)_3$ wherein at least one R^1 represents a lower alkyl group in at least one silane of formula, at least one R^1 represents a group containing a functional mercapto group, and any other R^1 groups may represent a phenyl group, or a functional group including at least one of vinyl, acrylic, amino, or vinyl chloride functional group; and R^2 represents a lower alkyl group; and
- 20
- 25

- ii) lower alkanol; and
 - b) curing the coating composition, thereby forming on the live tissue or the medical article substrate a coating that inhibits or prevents colonization or growth of microorganisms.
- 5 21. A method for inhibiting or preventing microbial infections comprising:
- a) applying to live tissue or a medical article substrate a composition which in combination with water, forms a neutral or basic composition, wherein the composition comprises the product obtained by combining in a lower alkanol solvent, at least two
10 silanes, represented independently by formula $R^1Si(OR^1)_3$ wherein at least one R^1 represents lower alkyl group, at least one R^1 represents a group, containing a functional amino group, any other R^1 group represents, phenyl, or a functional group including at least one of vinyl, acrylic, or vinyl chloride functional group,
15 R^2 represents lower alkyl group; and
 - b) curing the composition, thereby forming on the live tissue or the medical article substrate a coating that inhibits or prevents colonization or growth of microorganisms.
22. A method for inhibiting or preventing microbial infections comprising:
- 20 a) applying to live tissue or a medical article substrate a non-metallic non-aqueous coating composition formed by combining:
 - i) at least one silane of formula $R^1_nSi(OR^2)_{4-n}$ wherein R^1 represents a lower alkyl group, an aryl group or a functional group containing at least one of vinyl, acrylic,

-62-

amino, mercapto, or vinyl chloride functional groups; R^2 represents a lower alkyl group; and, n is a number of 1 to 2; and

5 ii) at least one compound selected from the group consisting of vinyltriacetoxysilane, colloidal aluminum hydroxide and at least one metal alcoholate of formula $M(OR^3)_m$ wherein M represents a metal of valence m, R^3 represents a lower alkyl group, and m is a number of 2 to 4; and

10 b) curing the coating composition, thereby forming on the live tissue or the medical article substrate a coating that inhibits or prevents colonization or growth of microorganisms.